THE BIODIVERSITY CRISIS AND ADAPTATION TO CLIMATE CHANGE: A CASE STUDY FROM AUSTRALIA'S FORESTS

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Abstract. If current trends continue, human activities will drastically alter most of the planet's remaining natural ecosystems and their composite biota within a few decades. Compounding the impacts on biodiversity from deleterious management practices is climate variability and change. The Intergovernmental Panel on Climate Change (IPCC) recently concluded that there is ample evidence to suggest climate change is likely to result in significant impacts on biological diversity. These impacts are likely to be exacerbated by the secondary effects of climate change such as changes in the occurrence of wildfire, insect outbreaks and similar disturbances. Current changes in climate are very different from those of the past due to their rate and magnitude, the direct effects of increased atmospheric CO_2 concentrations and because highly modified landscapes and an array of threatening processes limit the ability of terrestrial ecosystems and species to respond to changed conditions. One of the primary human adaptation option for conserving biodiversity is considered to be changes in management. The complex and overarching nature of climate change issues emphasises the need for greatly enhanced cooperation between scientists, policy makers, industry and the community to better understand key interactions and identify options for adaptation. A key challenge is to identify opportunities that facilitate sustainable development by making use of existing technologies and developing policies that enhance the resilience of climate-sensitive sectors. Measures to enhance the resilience of biodiversity must be considered in all of these activities if many ecosystem services essential to humanity are to be sustained. New institutional arrangements appear necessary at the regional and national level to ensure that policy initiatives and research directed at assessing and mitigating the vulnerability of biodiversity to climate change are complementary and undertaken strategically and cost-effectively. Policy implementation at the national level to meet responsibilities arising from the UNFCCC (*e.g.*, the Kyoto Protocol) and the UN Convention on Biological Diversity require greater coordination and integration between economic sectors, since many primary drivers of biodiversity loss and vulnerability are influenced at this level. A case study from the Australian continent is used to illustrate several key issues and discuss a basis for reform, including recommendations for facilitating adaptation to climate variability and change.

Key words: biodiversity, climate variability, climate change, adaptation, institutional reform.

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1. Introduction

Earth's biological diversity provides many of the ecosystem services essential to civilisation. Human activities now impair the flow of these services and, if current trends continue, will drastically alter most of the planet's remaining natural ecosystems and their composite biota within a few decades (Daily *et al.*, 1997). Compounding the impacts on biodiversity from deleterious management practices is climate variability and change. The recently published IPCC Regional Impacts Special Report (Watson *et al.*, 1998) concluded that there is ample evidence to suggest climate change is likely to result in significant impacts on biological diversity. Alterations in soil characteristics, water and nutrient cycling, plant productivity, species interactions (competition, predation, parasitism, *etc.*) and the structure and function of ecosystems have been identified as highly likely responses to increases in atmospheric CO_2 concentration and shifts in temperature and rainfall regimes. Impacts on biodiversity are also likely to be exacerbated by the secondary effects of climate change such as changes in the occurrence of wildfire, insect outbreaks and similar disturbances.

Our understanding of historical landscape patterns provides further evidence that climate affects the structure and function of ecosystems and the distribution and abundance of biota, especially at the regional scale. For example, palaeological studies show the distribution of ecosystems such as boreal and temperate forests has changed considerably over time, most recently during the last glaciation. Current changes in climate are critically different due to their rate and magnitude, the direct effects of increased atmospheric CO_2 concentrations and because highly modified landscapes and an array of threatening processes limit the ability of terrestrial ecosystems and species to respond to changed conditions, and constrain options for management and adaptation.

2. Some findings of the IPCC Regional Impacts Special Report

In the IPCC report (Watson *et al.*, 1998), the primary human adaptation option for conserving biodiversity was seen to be changes in management (*e.g.*, changes in land-use, control of pests and weeds and restoration of degraded areas). Climatic and ecological research, monitoring and prediction were identified as a necessary foundation to any adaptive response. Research into the human dimensions of adaptive management is also essential, including the capacity of current institutions and institutional arrangements to support policy processes that facilitate informed, flexible, precautionary approaches at the regional level. The complex and overarching nature of climate change issues emphasises the need for greatly enhanced institutional and interdisciplinary cooperation between scientists, policy makers, industry and the community to better understand key interactions and identify options for adaptation. Hence, research into the human dimensions of adaptive management is also essential. This research might include investigations of the capacity of current institutions and institutional arrangements to support policy processes that facilitate informed, flexible, precautionary approaches at the regional level. Limited knowledge means that society needs to structure investigations and debate to best use available information while still acknowledging and accommodating underlying uncertainty.

To illustrate some of the technical, institutional and policy challenges indicated above, this paper focusses on the management of biological diversity in Australia – giving emphasis to temperate, native forest ecosystems – and considers a number of issues raised by climate change.

3. A case study from Australia

From a global perspective, Australia's biological diversity is significant and has many unique attributes and a high level of endemism (Williams *et al.*, 1994). Given the continent's evolutionary history, the level of endemism is not surprising, but it is important for policy because it places a notable stewardship responsibility on Australia. This responsibility is amplified because, of the twelve recognised 'mega-diversity' countries of the world (Commonwealth of Australia 1996a), Australia is the only developed nation and is well placed to conserve biodiversity and manage its resources on an ecologically sustainable basis. However, a recent review of Australia's progress towards the goal of ecological sustainability (Commonwealth of Australia 1996b) concluded that there was little evidence that ecologically sustainable management and commitment to sustainability had been fully integrated into decision making. Progress towards sustainability was said to require recognition that the economy is a subset of human society, which in turn is part of the environment.

The biota of temperate forests are part of Australia's stewardship responsibility. This is illustrated by the suite of arboreal marsupials that is principally found in temperate forests and whose occurrence is strongly dependent on the availability of food and tree hollows for nest sites (Pausas *et al.*, 1997). The recently discovered moth that appears reliant on the availability of the scats of the Koala in which to deposit its eggs is another example of the interdependencies found in temperate forests (T.W. Norton, pers. comm.).

While the status of taxonomic knowledge in temperate forests in southern Australia compares favourably with other developed nations, major gaps in knowledge remain. Also of serious concern is the massive deficiency in knowledge of the distribution, abundance, interactions and functional roles of the vast majority of forest biota. Combined with on-going threatening processes and uncertainties, these gaps in knowledge hinder moves to sustainable management.

The Convention on Biological Diversity (CBD), of which Australia is a signatory, establishes a framework of general obligations that Parties are to elaborate in more detail at the national level. Most of the Conventions' obligations allow Parties some flexibility in implementation, recognising that conditions of biodiversity conservation and loss may vary widely (Dovers and Williams, in press). A National Strategy for the Conservation of Australia's Biodiversity (Commonwealth of Australia, 1996a) has been developed by the Australian government to fulfil the requirement of Article 6 of the CBD. While this is the central component of biodiversity policy in Australia, the overall policy setting, currently, is somewhat confusing and inefficient since it comprises some two hundred schemes, strategies, policies and programs. For example, the States and

Territories of Australia are individually establishing policy strategies to manage biodiversity and many integration aspects remain to be tackled.

3.1. MANAGING BIODIVERSITY

A host of factors can be important in determining the nature, composition and function of ecosystems, and the distribution, abundance, population dynamics and evolution of species. The evolutionary history of landscapes and evolutionary ecology of species sets the stage. Then factors such as the availability of key resources (*e.g.*, soil type and its effect on moisture and nutrient availability on plant performance), disturbance regimes, competition, predation, and dispersal ability become important for different biota. Resources necessary for the survival and reproduction of species may be patchily distributed in space (*e.g.*, across the landscape), and time (*e.g.*, between breeding cycles and dispersal phases of young). Complex interactions affecting the structure, function and resilience of ecosystems are increasingly demonstrated between biota in temperate forests (*e.g.*, between fungi, ground-dwelling marsupials, fire and eucalypts). The maintenance of biodiversity under global change requires a significantly enhanced understanding of such interactions.

Our understanding of historical landscape patterns provides further evidence that climate affects the structure and function of ecosystems and the distribution and abundance of biota and biodiversity, especially at the regional scale. Palaeological evidence shows that the distribution of temperate forests has changed considerably over time, most recently during the last glaciation around 10,000 years ago. A critical difference now is the highly modified landscapes that influence the ability of ecosystems and species to respond to changed conditions, and constrain options for management (*e.g.*, restoration). The current rate of environmental change is also of concern. Elevated levels of atmospheric CO_2 may also affect the response of species to changes in temperature and precipitation (Landsberg 1996).

A number of techniques are used to examine the potential impact of global change on biodiversity. Because of the uncertainties and complexities involved, a number of these approaches have a strong technical, modelling component. Bioclimatic modelling, where the current climatic envelope of a species is examined using different climate change scenarios, has been a widely used approach in Australia. For example, Brereton *et al.* (1995) used predictive models for bioclimatic ranges to examine the potential effect of enhanced greenhouse climate change on the distribution of 42 species of fauna in south-eastern Australia. In their analysis, forest species appeared to be less affected by climate change, which the authors felt might reflect the large altitudinal range of forest habitats in south-east Australia. Only two of the eleven forest species studied disappeared under a temperature rise of three degrees, both of which had very restricted ranges. Hughes *et al.* (1996) also used this approach to examine the distribution of eucalypt species under climate change and noted quite large displacements in the range of some species.

These types of studies recognise that climate is only one of the factors that may affect the distribution and abundance of species, and that the current climatic range is not necessarily indicative of the potential climate in which species can occur. In some instances, changed levels of atmospheric CO_2 are also likely to influence the ability of species to respond to altered climatic regimes. This possibility has not generally been accounted for in climatic models. The bioclimatic modelling approach generally focuses on the response of individual species to climate change. Another class of models, which has a more dynamic component, is the JABOWA/FORET type forest gap simulation models (Pausas *et al.*, 1997). The utility of this approach and the ability of these models to obtain accurate predictions under climate change scenarios is discussed by Austin *et al.* (1997).

Experimentation in the laboratory and field is also used to examine the potential response of species to global change. These generally focus on the response of individual plant species to elevated levels of CO_2, although a series of FACE (free-air CO_2 enrichment) experiments have been used overseas to examine ecosystem level responses (Mooney and Koch 1994). Studies such as those that examine the impact of human land-use (*i.e.*, fragmentation (Freidenburg 1998)) and the impact of weed species on natural ecosystems (Grice and Brown 1996) also add to our understanding of global change.

3.2. POSSIBLE ADAPTATIONS TO IMPACTS

The primary human adaptation option for responding to climate variability and change in Australasia has been identified as changes to land management practices such as forestry and increasing the control of pests and weeds (Basher *et al.*, 1998). Active manipulation was not seen as being generally feasible, except for rare and endangered species (Rosetta and Dixon 1997) and should be considered in recovery plans for such biota. In addition, if soil moisture availability becomes limiting to growth as a consequence of climate change, irrigation may be necessary for commercially valuable systems such as forestry operations. Under any circumstance, climatic and ecological research, monitoring and prediction are a necessary foundation to any adaptive response (Basher *et al.*, 1998).

Management prescriptions to address future global change options in natural areas generally fall into five categories (Halpin 1997)(Box 1). Because of the lack of experimental field testing, these options have been largely intuitive, based primarily on assumptions of future landscape needs. As identified by Halpin (1997), it would seem essential that future questions about biodiversity protection under global change shift from highly conceptual arguments to specific management proposals. This shift is beginning to occur in Australian forests managed primarily for nature conservation as well as those identified for production forestry. An example is addressing threatening processes such as the loss of hollow bearing trees via specific management actions (Norton 1996).

Box 1: Management prescriptions identified by Halpin (1997) to address future global change option in natural areas.
• selection of more than one conservation reserve for each important community type; • selection of reserves that provide habitat diversity; • management for buffer-zone flexibility; • management for landscape connectivity; and • management for habitat maintenance.

3.3. ASSESSING THE IMPACTS OF CLIMATE CHANGE

In Australia, considerable attention has been directed to the criteria and indicators developed for the conservation and sustainable management of temperate forests through the Montreal Process (Commonwealth of Australia 1997a, Box 2). While originally intended to assess progress towards sustainable management at the national level, these indicators have been adopted and modified at the regional level in Australia (Commonwealth of Australia 1997b), principally through the on-going Regional Forest Agreement process.

Box 2: Montreal Process Criteria which, along with their associated indicators, are used to assess the conservation and sustainable management of temperate and boreal forests.
Criterion 1: Conservation of biological diversity.
Criterion 2: Maintenance of productive capacity of forest ecosystems.
Criterion 3: Maintenance of forest ecosystem health and vitality.
Criterion 4: Conservation and maintenance of soil and water resources.
Criterion 5: Maintenance of forest contribution to global carbon cycles.
Criterion 6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies.
Criterion 7: Legal, institutional and economic framework for forest conservation and sustainable management.

Criterion 1 of the Montreal Process relates to the conservation of biological diversity, focusing on indicators of ecosystem, species and genetic diversity. At the national level, Criterion 5 addresses the maintenance of forest contribution to global carbon cycles. There is, however, only one indicator that specifically addresses the ability to predict impacts of climate change on forests. This indicator is not considered relevant at the regional level and, therefore, limits the effectiveness of this approach to measure climate change impacts. This aspect will need to be addressed to support moves towards the sustainable management of temperate forest ecosystems in Australia.

The complex and overarching nature of climate change emphasises the need for interdisciplinary research and to explicitly incorporate human land-use when developing and using biophysical models of climate-ecosystem interactions. The task of biodiversity managers is further complicated by the complex policy and legislative framework that presently exists in Australia (Dovers and Williams, in press). Resolving these issues in a systematic and effective manner will undoubtedly generate important insights relevant to many other areas of the planet.

4. Some recommendations

The Sustainable Biosphere Initiative (SBI) of the Ecological Society of America (Lubchenco *et al.*, 1991) has identified biodiversity, global change and sustainable eco-systems as priority areas. The SBI addresses these areas on three fronts – research, education, environmental decision making – and provides a useful framework for considering how to achieve biodiversity conservation goals given climate variability and change.

4.1. RESEARCH

Several ecological research areas have been identified by Halpin (1997) if progress is to be made on responding to global change and establishing scientifically-based strategies to conserve biological diversity (Box 3). These represent a useful starting point for detailed discussion and debate. Research on these topics is also likely to be most productive if linked to and/or complemented by interdisciplinary studies of land-use and the effects of climate change.

Box 3: Ecological research areas identified by Halpin (1997) to make progress on responding to global change.
• well-defined sensitivity tests are needed of ecosystem responses at the site or sub-regional scale; • analysis of the fundamental physiological tolerances, competitive interactions and dispersal mechanisms of key species are required to better understand the potential response of existing ecosystems to change; • analysis of changes in local disturbance regimes (i.e. storm, fire, drought, pests) are required to understand and predict rapid changes in ecosystem properties and stability; • analysis of the interaction between landscape fragmentation and the mobility and dynamics of populations are needed to better characterise current and future ecosystem controls; • it seems appropriate to critically evaluate suggested management interventions both in terms of ecological viability and likely benefit-costs.

4.2. EDUCATION

By providing information that links climate change and land-use, scientists can assist policy makers, stakeholders and the general public reduce the impacts of global change on biodiversity (Dale 1997). This may also help to define what climate change would mean in an ecological, social, health, political and economic sense and how society in general can contribute to biodiversity conservation. Different groups will have different information requirements and educational material must be designed accordingly. For example school children and land managers will require different approaches. While concisely written material such as 'fact sheets' have a role to play, private land managers in Australia generally prefer face to face discussions about natural resource issues. This underlies the importance of supporting extension services to maximise the transfer of knowledge.

4.3. ENVIRONMENTAL DECISION MAKING

While a number of approaches and techniques to address the uncertainty inherent in management of biodiversity have been proposed, none can be completely relied upon to provide incontestable policy or management recommendations; some subjective and political decisions will usually remain. Hence one important question is how to structure investigations and debate so as to best use available knowledge while still acknowledging the underlying or attendant uncertainty. This is a point equally relevant to scientists and policy makers, and clearly directs our attention to the nature of policy processes and institutions to enable informed, flexible, precautionary approaches. This topic area has received increasing attention by researchers and practitioners in the past decade (*e.g.*, see Dovers *et al.*, 1996), but needs much greater investigation.

5. Conclusions

Current regional assessments of climate change (Watson *et al.*, 1998) indicate that a key challenge is to identify opportunities that facilitate sustainable development by making use of existing technologies and developing policies that enhance the resilience of climate-sensitive sectors. In addition, these regional assessments demonstrate the need for anticipation and planning since failure to do so may lead to capital-intensive development of infrastructure and research and development that is ill-suited to future conditions. Measures to enhance the resilience of biodiversity must be considered in all of these activities if many ecosystem services essential to humanity are to be sustained.

To address these needs, new institutional arrangements seem likely to be required at the regional and national level. These would help ensure that policy initiatives and research directed at assessing and mitigating the vulnerability of biodiversity to climate change are complementary and undertaken strategically and cost-effectively. Policy implementation at the national level to meet responsibilities arising from the UNFCCC and the UN Convention on Biological Diversity require greater coordination and integration between economic sectors, since many primary drivers of biodiversity loss and vulnerability are influenced at this level. A topical example is the planned broadscale plantings in Australia to meet commitments negotiated in the Kyoto Protocol. These plantings could also meet biodiversity objectives such as linking patches of remnant native vegetation. Devising strategies that accommodate these cross-scale and sector linkages would appear to be a high priority. Providing the right mix of incentives for encouraging sustainable resource management, especially on privately owned land, is another. This brief case study from the Australian continent outlined above is but one illustration of many available globally that suggest the need for reform if society is to be well placed to adapt to climate variability and change.

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